MSC-PA-R-69-2
Anomaly Report No. 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 9

LOW REGULATION PRESSURE IN ASCENT PROPULSION SYSTEM

DISTRIBUTION AND REFERENCING

This paper is not suitable for general distribution or referencing. It may be referenced only in other working correspondence and documents by participating organizations.

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
OCTOBER 1969

(NASA-TM-X-69416) APOLLO 9: LOW REGULATION PRESSURE IN ASCENT PROPULSION SYSTEM (NASA) 10 p

N74-70517

Unclas
00/99 16275

MSC-PA-R-69-2
Anomaly Report No. 1

APOLLO 9 MISSION

LOW REGULATION PRESSURE IN ASCENT PROPULSION SYSTEM

PREPARED BY

Mission Evaluation Team

APPROVED BY

James A. McDivitt
Colonel, USAF
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

August 1970

LOW REGULATION PRESSURE IN ASCENT PROPULSION SYSTEM

STATEMENT

During the unmanned ascent engine firing to depletion on Apollo 9, the regulated helium pressure supplied to the propellant tanks (fig. 1) dropped from the lockup pressure of 186.5 psia to a stabilized value of 176.5 psia, 7.5 psi below the expected regulation pressure. Correspondingly, the engine propellant feed pressures and the chamber pressure stabilized at levels below intended values. At about 3 minutes into the firing, the regulated helium pressure had dropped to 175 psia. Shortly thereafter, the pressure rose rapidly to 179 psia and stabilized. During this period, the helium tank and regulator inlet pressures changed markedly in slope, showing an increase in helium flow rate. After engine shutdown, the regulated pressure locked up at the proper pressure.

DISCUSSION

The ascent propellant tanks are supplied with pressurizing helium by two redundant parallel helium regulator legs, each consisting of two regulators in series (fig. 2). The two parallel legs protect against a failed-closed regulator, and the two series regulators in each leg protect against both a failed-open regulator and one that will not lock up. A filter is installed upstream of each regulator leg to protect the leg from contamination. In addition, an integral filter is included in the inlet of the upstream regulator in each leg. During normal operation, one regulator leg (class I) will supply most of the flow, and the outlet pressure will be regulated by the primary unit in that leg.

The low regulation pressure (176.5 psia) for the first 290 seconds of the firing could have been caused by a downshift in the regulation range of the primary regulator in the class I leg or by a flow restriction in the regulator in the class I leg, causing the class II leg to supply most of the flow and its primary regulator to control outlet pressure. To determine whether the class I regulator leg attempted to flow during the engine start, a test was conducted assuming the class I leg was inoperative. The system was pressurized by the class I regulators to their lockup level. Then, the solenoid valve in the class I leg was closed, followed by an engine firing, thereby forcing control through the class II leg. This test verified that the Apollo 9 system had little or no flow until the pressures dropped to the primary regulator level of the class II leg.

At 290 seconds into the firing, the pressures in the regulator manifold increased 4 psi in 1-1/2 seconds. This increase was also experienced at the engine interface; however, the pressure rise time was 20 seconds, corresponding to the time to increase the ullage pressure. Three possibilities could have caused the step increase.

1. An upshift in the regulation level of the class II primary regulator was considered; however, the general characteristic of the regulators is to decrease in regulation pressure as supply pressure decreases. Therefore, this possibility is unlikely.

2. Tests have shown that when two regulators share the 1.2-lb/min flow, the regulation levels are increased above the levels of either. Based upon this knowledge, it was hypothesized for LM-3 that one regulation leg was flowing during the first 290 seconds of firing, at which time the controlling regulator outlet pressure dropped to the level of the other leg, causing a flow in both regulator legs. Test results showed a slight increase in regulation level (fig. 3), but the increase was a gradual change and not a step function as experienced on Apollo 9. Therefore, the rise in regulated pressure cannot be attributed to a possible regulation-sharing phenomenon.

3. The step increase was duplicated in tests by allowing the class I regulator leg to start controlling, shutting off flow in the class II leg (fig. 3). This was accomplished by setting regulation bands 4 psi apart, with the class I solenoid valve closed at the start of the firing. Opening of the solenoid valve allowed the class I regulator to start flowing and duplicated pressure increases observed during Apollo 9.

The depletion characteristics of the LM-3 helium system were such that both class I and class II legs were flowing normally as verified by comparison of depletion characteristics with ground test results.

One of the following failure modes appears most likely, based on an analysis of assumed conditions. (Figure 4 shows a cutaway view of the regulator.)

1. A regulation band shift caused by contamination, creating a restriction to flow in the feedback line from pilot poppet to main stage piston.

2. Contamination preventing movement of the main poppet sleeve and guide, piston, or guide and body in response to outlet pressure demand.

3. Galling of the main piston in the bearing area, causing unstable regulation, including downshift and subsequent recovery.

Regulator failure history shows that three units have failed closed. However, none of these satisfy the conditions observed in flight. Three units have experienced regulation downshift, and one later recovered. The engine filters downstream of this regulator were previously found to be contaminated with steel and Teflon chips.

The solenoid valve upstream of the LM-3 class I primary regulator was removed at the launch site. Both legs were backflowed during change-out of this valve, possibly introducing contamination into both legs.

CONCLUSIONS

The cause of the anomaly cannot be conclusively established; however, the following conclusions have been drawn:

1. The class II regulator leg supplied most of the flow and controlled regulator outlet pressure for the first 290 seconds of the firing.

2. The step-up in regulation pressure at 290 seconds into the firing resulted when the class I regulator started to flow.

3. Both class I and class II regulators were flowing normally at the time of depletion.

4. The most probable cause of the anomaly was contamination, introduced by backflow through the regulator during solenoid valve replacement.

CORRECTIVE ACTION

Review of vehicle checkout results and repair histories cannot eliminate the possibility that backflow has occurred for vehicles through LM-7. However, regulators for these spacecraft have been functionally tested and found to operate within specification limits.

For subsequent lunar modules on which replacement of components is necessary, the tubing on both sides of the defective component will be cut. The tube bore will be visually inspected and wiped out with a swab to remove any chips formed by the tubing cutter. The line ends will then be deburred using a tool incorporating a plastic contaminant barrier which slides into the tube ahead of the tool. This barrier wipes the tube bore during removal. The deburring tool also includes a vacuum attachment which picks up chips formed during the deburring operation. Previously, the tubing was purged during the deburring operation to sweep out any contaminants formed. In the future, no purge or flow of any kind will be used. This procedure was successfully used during a solenoid valve replacement on LM-7.

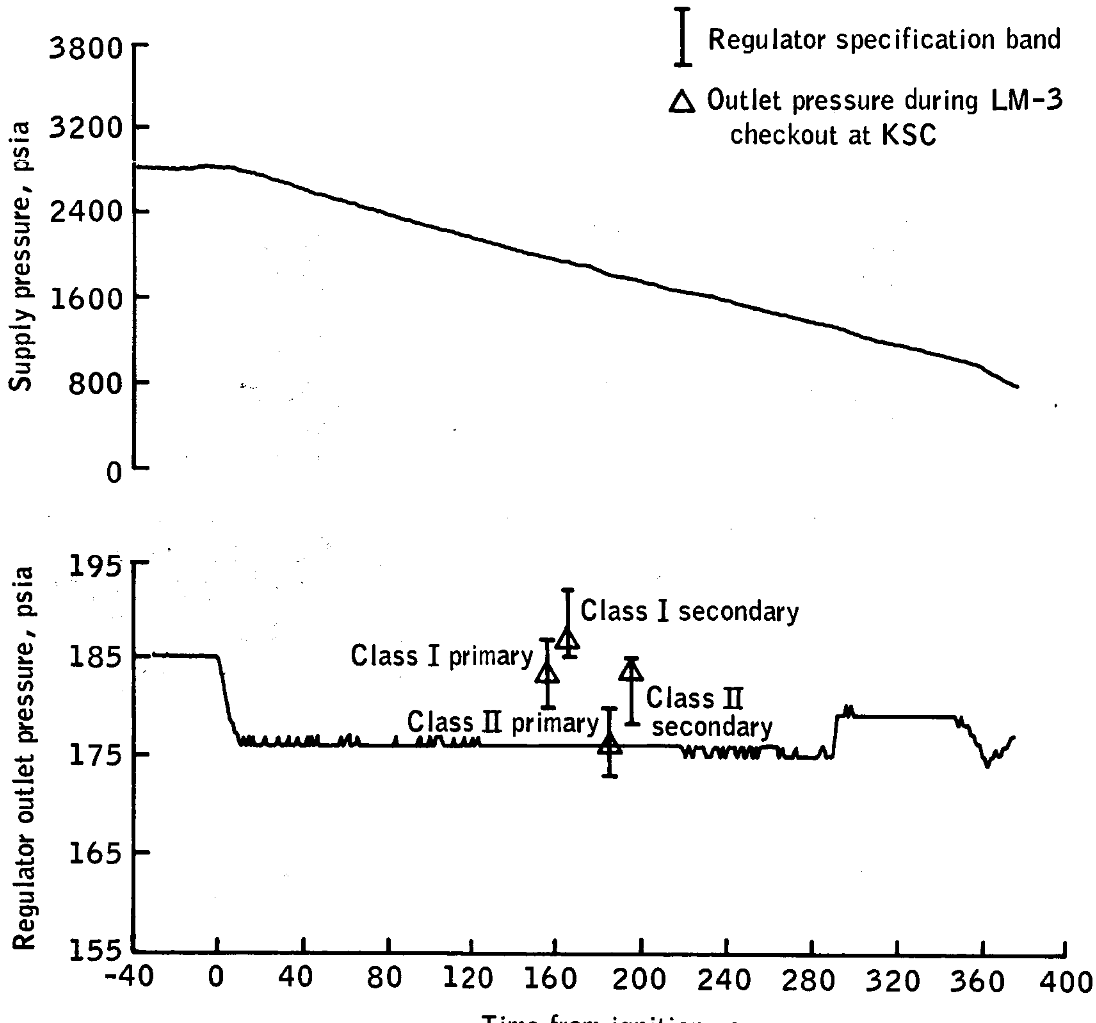

Figure 1.- Pressures during firing to depletion.

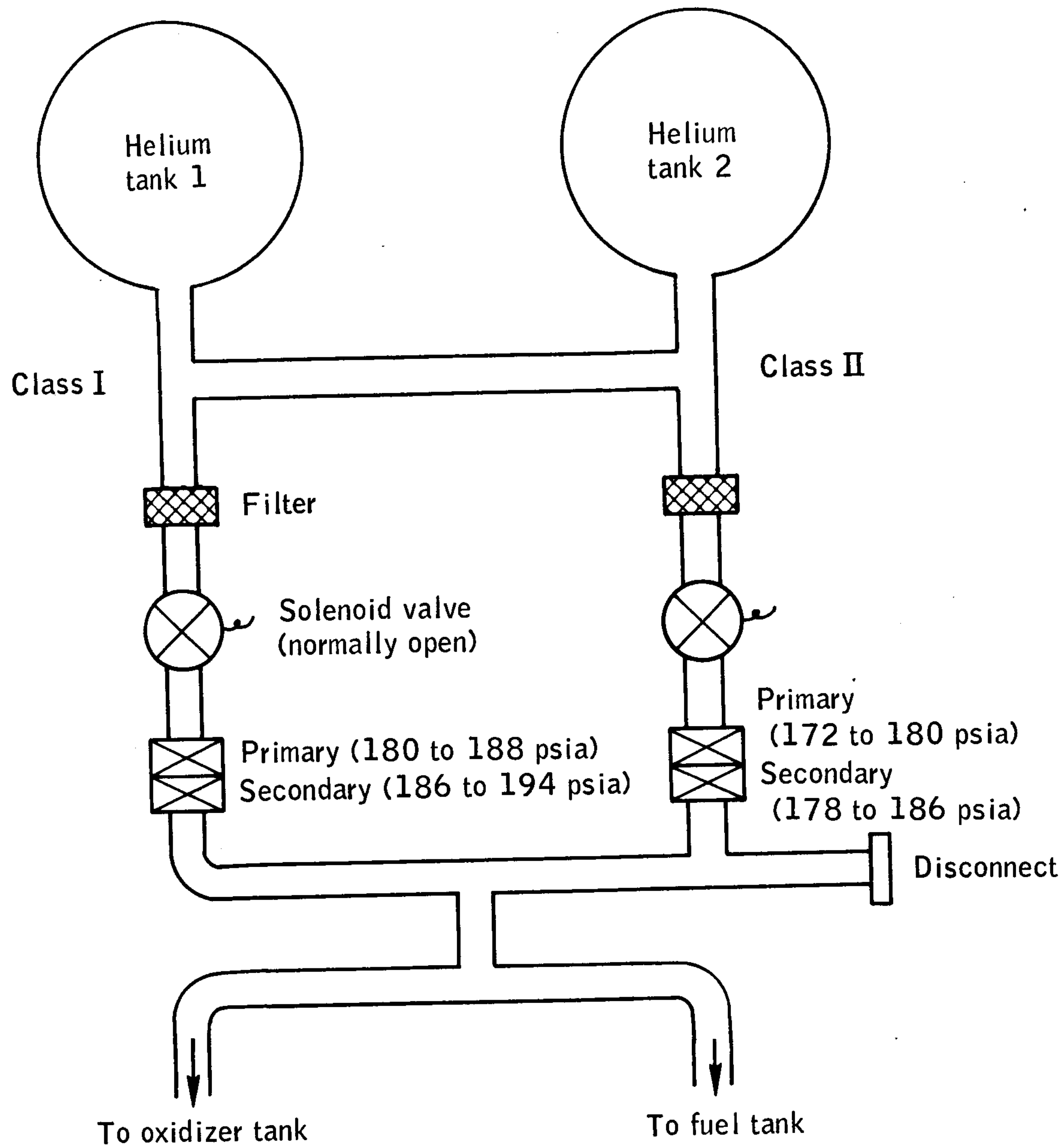

Figure 2.- Ascent propulsion pressurization system.

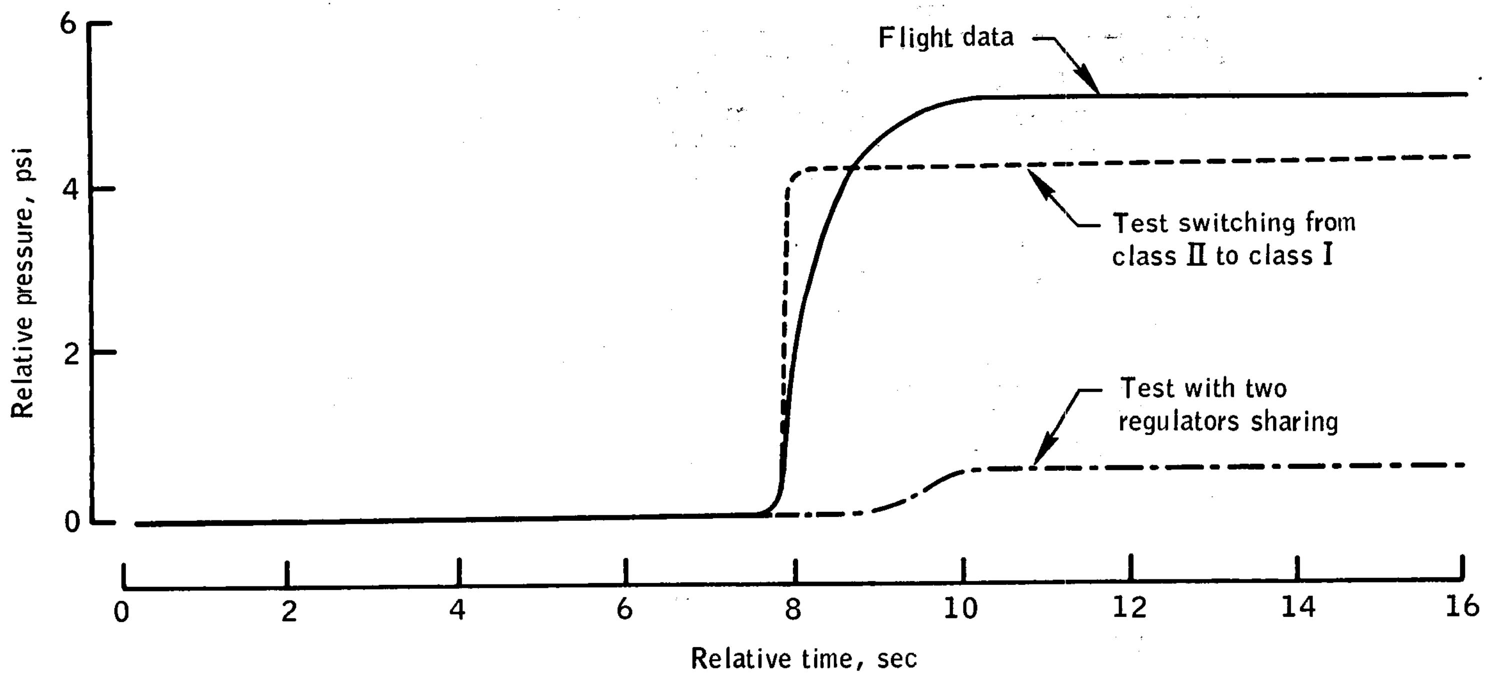

Figure 3.- Changes in regulator outlet pressures.

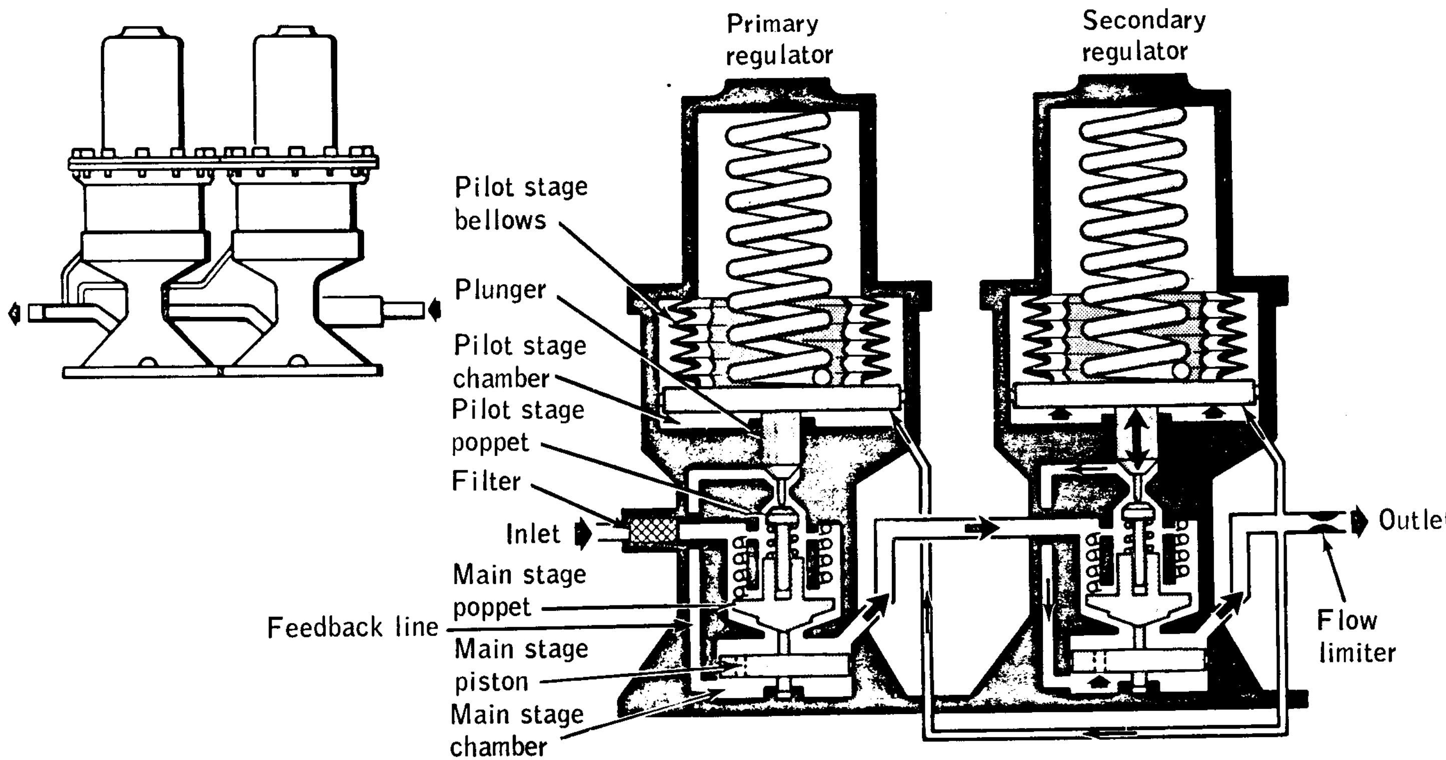

Figure 4.- Helium regulator.

NASA — MSC